Heating ventilation and air conditioning

Environment, Air

Heating, ventilation and air conditioning (HVAC) constitutes up to 35 percent of energy used in manufacturing facilities.

HVAC stands for heating, ventilation and air conditioning and refers to the equipment, distribution network and terminals used either collectively or individually to provide fresh filtered air, heating, cooling and humidity control in a building.

A facility can have any combination of heating and cooling sources to supply the HVAC system. For heating a facility, a gas-or oil-fired boiler or furnace, heat pump, rooftop unit, new technology such as infrared radiation, or electric heat could be employed. Common cooling sources include rooftop units, chillers, heat pumps, air conditioner or some sort of off-peak cooling system.

The Basic HVAC Design

HVAC systems can vary in design and complexity.

Air is taken through an outdoor air intake that is usually a louvered opening on the top or side of the building. Atmospheric pressure pushes the air through a damper, which regulates the amount of outdoor air (OA) taken in by the system. At this point, already conditioned return air (RA) from the system can be mixed with the outdoor air to form “ mixed air.” The mixed air goes through pre-filter where larger dust particles; insects, leaves, etc. are caught. A more efficient filter is usually present to address small particles. After the filters, the air enters a centrifugal fan. Once exiting the fan outlet, the air is under positive pressure and being

Pushed towards coils where the air is either heated or cooled, depending on the temperature of the air and the season. Under the coils lies a drain pan to collect any water condensing on the coils. If a humidifier or dehumidifier is needed it is usually incorporated into the cycle at this point. The air travels through ductwork where it reaches a distribution box and may travel through smaller ducts to supply the terminals, registers or diffusers into the workspace. Once the air reaches its destination, it is returned through an air register (usually through a louvered door that opens into a space above the ceiling tiles) in the form of return air that will become mixed air or exit the building.

Air Conditioning

Air conditioning is treating air for temperature, cleanliness and humidity, and directing its distribution to meet requirements of a conditioned space. Comfort air conditioning is when the primary function of the system is to provide comfort to occupants of the conditioned space. The term industrial air conditioning is used when the primary function is other than comfort.

There are three basic types of air conditioners:

ô€, ƒ Direct expansion coolers include window air conditioners, heat pumps and packaged or rooftop units. Air is cooled and dehumidified as it moves past a cold, refrigerant-filled coil.

ô€, ƒ Chilled water systems use water cooled by a refrigeration machine instead of air. This cool water supplies a coil, which cools and dehumidifies the air.

ô€, ƒ Evaporative (or “ swamp”) coolers are usually only appropriate in hot, dry climates and bring hot air in contact with a water spray or damp surface. The result is evaporation of moisture, which lowers the temperature of the air.

What is Ventilation

Ventilation is a process that either supplies or removes air from a space by natural or mechanical means. All air that is exhausted from a building must be replaced by outside air. Outside air must be brought to a certain temperature by makeup air units used throughout the building. Negative building pressure can be a problem during winter heating season and could lead to a number of other problems such as difficulty in opening doors and equipment operation. Air seeps through gaps around windows, doors and ducts.

While designing HVAC systems for energy efficiency-cy, it is also good to take into account the design for human comfort. Good working conditions increase productivity and employee satisfaction. The HVAC design should incorporate:

ô€‚ƒ a determination of indoor conditions and how energy use is affected;

ô€‚ƒ the impact on equipment selection, ducting and register design; and

ô€‚ƒ determination whether certain conditions will be acceptable for comfort criterion.

Heating, Ventilation and Air-Conditioning (HVAC) Systems

The main purposes of a Heating, Ventilation, and Air-Conditioning (HVAC) system are to help maintain good indoor air quality through adequate ventilation with filtration and provide thermal comfort. The choice and design of the HVAC system can also affect many other high performance goals, including water consumption (water cooled air conditioning equipment) and acoustics.

Codes and Standards

Many state codes also specify minimum energy efficiency requirements, ventilation controls, pipe and duct insulation and sealing, and system sizing, among other factors. In addition, some states and localities have established ventilation and other indoor air quality related requirements that must also be followed.

Design in accordance with ASHRAE standards Design systems to provide outdoor air ventilation in accord with ASHRAE Standard 62. 1-2007 and thermal comfort in accord with ASHRAE Standard 55-1992 (with 1995 Addenda) Thermal Environmental Conditions for Human Occupancy

Ensure familiarity with, and adherence to, all state and local building codes and standards.

Potential for Natural Ventilation and Operable Windows

In some parts of the country, where temperature and humidity levels permit, natural ventilation through operable windows can be an effective and energy-efficient way to supplement HVAC systems to provide outside air ventilation, cooling, and thermal comfort when conditions permit (e. g., temperature, humidity, outdoor air pollution levels, precipitation). Windows that open and close can enhance occupants' sense of well-being and feeling of control over their environment. They can also provide supplemental exhaust ventilation during renovation activities that may introduce pollutants into the space.

However, sealed buildings with appropriately designed and operated HVAC systems can often provide better indoor air quality than a building with operable windows. Uncontrolled ventilation with outdoor air can allow outdoor air contaminants to bypass filters, potentially disrupt the balance of the mechanical ventilation equipment, and permit the introduction of excess moisture if access is not controlled.

Strategies using natural ventilation include wind driven cross-ventilation and stack ventilation that employs the difference in air densities to provide air movement across a space. Both types of natural ventilation require careful engineering to ensure convective flows. The proper sizing and placement of openings is critical and the flow of air from entry to exit must not be obstructed (e. g., by closed perimeter rooms).

Designers should consider the use of natural ventilation and operable windows to supplement mechanical ventilation. Consider outdoor sources of pollutants (including building exhausts and vehicle traffic) and noise when determining if and where to provide operable windows.

If operable windows will be used to supplement the HVAC system, ensure that:

openings for outdoor air are located between 3-6 feet from the floor (head height);

the windows are adjustable and can close tightly and securely;

the windows are placed to take maximum advantage of wind direction, with openings on opposite sides of the building to maximize cross-ventilation.

Selection of HVAC Equipment

In most parts of the country, climatic conditions require that outdoor air must be heated and cooled to provide acceptable thermal comfort for building occupants, requiring the addition of HVAC systems. The selection of equipment for heating, cooling and ventilating the school building is a complex design decision that must balance a great many factors, including heating and cooling needs, energy efficiency, humidity control, potential for natural ventilation, adherence to codes and standards, outdoor air quantity and quality, indoor air quality, and cost.

Where feasible, use central HVAC air handling units (AHUs) that serve multiple rooms in lieu of unit ventilators or individual heat pumps.

Although there are many different types of air handling units, for general IAQ implications in schools, air handling units can be divided into two groups: unit ventilators and individual heat pump units that serve a single room without ducts; and central air handling units that serve several rooms via duct work. Unit ventilators and heat pumps have the advantage of reduced floor space requirements, and they do not recirculate air between rooms. However, it is more difficult to assure proper maintenance of multiple units over time, and they present additional opportunities for moisture problems through the wall penetration and from drain pan and discharge problems. Central air handling units have a number of advantages as compared to unit ventilators and heat pumps serving individual rooms.

Features for air handling units:

Double-sloped drain pan and drain trap depth

Double-sloped drain pan – A double-sloped pan prevents water from standing and stagnating in the pan.

Non-corroding drain pan – Made from stainless steel or plastic. Prevents corrosion that would cause water to leak inside the AHU.

Easy access doors – All access doors are hinged and use quick release latches that do not require tools to open. Easy access to filters, drain pans, and cooling coils is imperative.

Double wall cabinet – The inner wall protects the insulation from moisture and mechanical damage, increases sound dampening, and is easier to clean.

Tightly sealed cabinet – Small yet continuous air leaks in and out of the AHU cabinet can affect IAQ and energy. The greatest pressure differentials driving leaks occur at the AHU.

Double wall doors with gaskets – Double wall doors provide better thermal and acoustic insulation, and will remain flatter, allowing a better seal against door frame gaskets

Minimum 2 inch thick filter slots – For better protection of the indoor environment, as well as the equipment and ducts, the filters slots should be able to accommodate 2 in. or thicker filters.

Extended surface area filter bank – To reduce the frequency of filter maintenance and the cost of fan energy, the bank is designed to allow more filter area, such as the deep V approach or bags.

Air filter assemblies (racks & housings) designed for minimum leakage – The filter bank should have gaskets and sealants at all points where air could easily bypass the air filters, such as between the filter rack and the access door. Use properly gasketed manufacturer supplied filter rack spacers.

Air filter monitor – A differential pressure gauge to indicate the static pressure drop across the filter bank. This feature could easily be installed as an option in the field.

Corrosion resistant dampers & links – All moving parts such as pivot pins, damper actuators, and linkages are able to withstand weather and moisture-induced corrosion for the full life of the system

Location of Outdoor Air Intakes and Exhaust

Sloped Intake Plenum and Accessible Intake Screen

Proper location of outdoor air intakes can minimize the blockage of airflow and intake of contaminated air.

The bottom of air intakes should be at least 8 inches above horizontal surfaces (generally the ground or the roof) to prevent blockage from leaves or snow. In northern locations, more separation may be needed due to greater snow depths or drifting snow.

Intakes should not be placed within 25 feet of any potential sources of air contaminants, including sewer vents, exhaust air from the building, loading docks, loading areas, garbage receptacles, boiler or generator exhausts, and mist from cooling towers.

If the source is large or contains strong contaminants, or if there is a dominant wind direction in the area, the minimum separation distance may need to be increased. Air admittance valves, an inexpensive and code-approved one-way air valve, can be added to sewer vents to eliminate the potential for release of gases into the surrounding air.

Grilles protecting air intakes should be bird- and rodent-proofed to prevent perching, roosting, and nesting.

Waste from birds and other pests (e. g., rats) can disrupt proper operation of the HVAC system, promote microbial growth and cause human disease. The use of outdoor air intake grilles with vertical louvers, as opposed to horizontal louvers, will reduce the potential for roosting.

Intake Screens must be accessible for inspection and cleaning.

In existing buildings, an insufficient amount of ventilation air is often the result of clogged intake screens that are inaccessible for inspection and cleaning. Screens hidden by an intake grille should be designed with a grille that is easily opened, such as a hinged grille with two quick-release latches, or in the worst case, a grille with four one-quarter turn fasteners. All screens should be easily removable for cleaning.

Consider adding a section of sloped intake plenum that causes moisture to flow to the outside or to a drain if intake grilles are not designed to completely eliminate the intake of rain or snow.

Air Distribution and Duct Insulation

Dirt and moisture should not be present in duct systems, and must be controlled to prevent mold growth. However, it is not always possible to assure that ducts remain dirt and moisture free. In many existing buildings, sheet metal ducts, as well as those constructed of or lined with insulation products, are often contaminated with mold because dirt and moisture found their way into the system.

Duct board and duct liner are widely used in duct systems because of their excellent acoustic, thermal, and condensation control properties. If the HVAC system is properly designed, fabricated, installed, operated and maintained, these duct systems pose no greater risk of mold growth than duct systems made of sheet metal or any other materials.

However, the very properties that make duct board and duct liner superior insulators (e. g., a fibrous structure with large surface area that creates insulating air pockets), also makes them capable of trapping and retaining moisture if they do get wet (though the fibers themselves do not absorb moisture).

While there is an ongoing debate about the wisdom of using insulation materials in duct systems that might retain moisture longer, all sides agree that extraordinary attention to preventing moisture contamination of the duct work should be the primary strategy for preventing mold growth.

As a secondary strategy, designers should consider methods of reducing the potential for future problems to occur due to unforeseen moisture contamination by investigating insulation products now on the market that minimize the potential for moisture to penetrate the insulation material. These include foil vapor retarders, tightly bonded non-woven vapor retarders, butt or shiplap edges, and other techniques that have been developed by insulation manufacturers to address concerns about moisture.

http://www. epa. gov/iaq/schooldesign/hvac. html

Water supply

Water has the unfortunate quality of being heavier than air. it weighs 62. 4 pounds per cubic foot. This mass requires a pressure of 0. 433 psi to lift water one foot (62. 4 lbs/144 in in ft). To put it another way, one psi will lift water 2. 31 feet (1/0. 433). In a single story building with 70 psi in the street, this can be insignificant. In a high-rise building, this factor will drive the design of both the hot and cold water systems.

First, high and low pressures need to be determined. Plumbing codes usually limit the high water pressure to 80 psi. Using 70 psi will result in more manageable flow rates at the fixtures, reduced water hammer and lower velocities. These characteristics will result in lower operating costs and a longer life of the system.

Codes often limit the low water pressure to 20 psi, unless there are fixtures such as flush valves that require greater pressures. Nevertheless, a minimum pressure of 40 psi is recommended for the comfort of the end users. With a pressure differential of 30 psi, a zone can be no more than 69 feet in height (30 ft x2. 31 ft/psi). Using a typical floor to floor height, for a hotel, of 11 feet, no more than six floors can be served by a single zone.

The next step is to determine the system pressure. The suction pressure can be determined by adding the street pressure and the elevation gain (assuming your booster pump is in the basement). Adding the anticipated losses including friction, elevation and PRV falloff to the minimum pressure results in the system pressure. Subtracting this from the street pressure yields the boost pressure. The manufacturer will also need to account for internal losses in the booster pump system.

Booster pumps today can be configured in any number of ways. With advancements in pumping technology, vented roof tanks are a thing of the past. A constant speed pump, carefully calculated, could operate without PRVs. If so, PRVs might be required at the top floor, and shutoff head must be checked. Shutoff head is the system pressure resulting from the demand approaching zero. It can be determined by adding the suction pressure to the pressure indicated on the far left end of the pump curve. In some cases, this pressure can exceed the capacity of the piping system. If PRVs are provided on the pump discharge, problems with shutoff head can be eliminated outside of the booster pump package but must still be checked within the package. A better solution is a variable speed booster pump. By tracking pressure, flow or electrical current, a variable speed booster pump can deliver constant pressure at any flow rate. This provides a more predictable system pressure and saves electricity at the same time.

Regardless of pump type, the lower zones in a high rise will need PRVs.

In most cases, for economical reasons, direct acting PRVs are used. A more consistent pressure can be maintained by using two valves piped in parallel (figure 1). The smaller valve may be sized to handle 1/3 of the flow rate at an acceptable falloff pressure. The larger valve is then sized for 2/3 of the flow rate at the same falloff pressure. If the smaller valve is set for 75 psi and the larger valve is set for 70 psi, then under low flow the larger valve will be closed and the smaller, more accurate valve will regulate the pressure. A relief valve is required downstream of the PRVs and will require an indirect waste receptor, which is often overlooked in the design of these stations. In many cases, the lowest of all zones may not require a boost in pressure. If so, a separate branch in the main, prior to the booster pump, could serve several lower floors, saving installation and utility costs.

The maximum number of floors that can be served depends on the materials used. The booster pump, valves, piping and appurtenances must all be capable of handling the maximum pressure at the base of the riser. Understanding pressure ratings can get quite involved. Bronze, threaded, class 150 valves are limited to 200 psi at 150 F, while the more expensive class 200 valves are limited to 400 psi. Iron, class 125 valves up to 12″ in size are also limited to 200 psi at 150 F, while the more expensive class 250 valves are limited to 500 psi. The correct valves must be specified in the booster pump package and in the piping system, at least for the lower floors.

At higher floors, the pressure falls; good practice is to reduce the class of valves when a safe working pressure has been reached. Pressure gauges and other small devices are often overlooked, along with, surprisingly, the piping. The maximum safe working pressure of 6″ hard drawn copper tube at 150 F is 376 psi, and the maximum gauge working pressure of the solder joint (assuming 95-5 tin-antimony solder) is 375 psi, but the rated internal working pressure of the fitting is only 213 psi. As such, serving more than 40 floors can be difficult at best.

One solution, to add a few more floors, is to use stainless steel pipe. The typical joint working pressure of schedule 10S can be 300 psi and schedule

40S can be 600 psi depending on the couplings used. When serving even taller high rise buildings, a secondary pumping station must be used (figure 2). In this scenario, a lower pump serves the bottom half of the building and also feeds the suction side of the higher pump, which in turn serves the top half of the building.

Particular attention must be given to the simultaneous control of these pump sets; a buffer tank may be necessary to maintain a constant suction pressure at the higher tank Alternatively, two lower pumps can be provided, one for the lower fixtures and one to feed the higher pump. This separation of the upper and lower building systems will allow for more independent control over pressures and can be useful for maintenance.

In most high rises, the water is pumped up to the PRV stations that are located at the top of the zones. The downstream risers and branch piping then downfeed to the fixtures. This decision, however, can be affected by the type of fixtures and the location of the hot water heater. In an upfeed system, the pressure loss due to friction and the pressure loss due to elevation are additive; the worst case is the top of the system where the pressure is lowest. In a downfeed system, at least for smaller pipe sizes, the friction pressure loss will be somewhat offset by the pressure gain from downfeeding. Also, since the friction loss is greatest at the bottom of the system where the pressure is greatest, smaller branch pipes can be utilized. The result is a more consistent static and dynamic pressure, providing a better experience for the end user.

An economic analysis often reveals that the cost of the express riser, the upfeed pipe that has no connections, is less than the savings from the smaller branch piping. It is strongly recommended that the hot and cold water in any building feed in the same direction. Otherwise, the cold water friction losses may be at a minimum where the hot water friction losses are at a maximum. Even with pressure balancing shower valves, a differential pressure of 50% could have disastrous results. If the water heater is on the roof, a downfeed system makes good sense.

The design of hot water systems is outside of the scope of this article. Engineers often return this hot water to the central water heater. Doing so can create a system that is very difficult to balance. Even when each zone is protected by a check valve, the pressure from the higher zone will often prevent the lower zones from circulating at all. A better approach is to circulate within each zone (figure 3). A fractional horsepower pump and a small electric tank type heater work well. Five gallons and three to nine kilowatts will handle six floors of almost any footprint since the water is only reheating from 110 F to 120 F. Since the pressure is already reduced, the circulating pump and reheat tank can be placed on any floor. Don’t forget about the main hot water riser. It must still be circulated back to the central system to ensure that this large column of water does not get cold overnight.

One final issue to consider in both hot and cold water distribution is the ability to purge air from the system. There are manual air vents the best way to purge air from the system is simply to provide horizontal distribution on the floor below the highest floor in each zone. This allows the air to collect in each riser and float to the top, where it is purged every time that a fixture on the top floor is used. This is rarely noticed by the end user unless the fixture is seldom used.

http://www. plumbingengineer. com/june_08/highrise_feature. php

Drainage

Pressure control on the drainage side presents other challenges. water is essentially the same in either system; however, drainage theory holds that considerable air travels downward with the water flow. This theory asserts that water flowing in a vertical pipe tends to adhere to the pipe's walls, acting very much like a sleeve of water with a hollow core of air, all sliding down the pipe's walls until it reaches a ratio of approximately 6/24 full of the pipe cross-sectional area. This watery sleeve travels at almost 15 feet per second (fps), propelled by gravity but restricted by friction. When the piping remains vertical, the entrained air is relatively simple to control, but when piping offsets from the vertical, the fluid flow velocity drops considerably, filling the entire pipe diameter. Horizontal, sloped drainage piping should flow in the 4-8 fps range, so it is easy to see that a large slug of water can quickly develop. This can lead to compressing air in the path of the fluid and/or lowering air pressure on the leaving side of the fluid flow. The impact of these fluid and air fluctuations can be controlled by effective use of yoke vents, relief vents, and vent connections at the bases of stacks. the solutions are largely not unique and have been used successfully on many intermediate-height and even extremely tall high-rise buildings.

A related concern is the impact of the hydraulic jump on the piping itself. The mass of water and the rapid change of velocity from vertical to horizontal cause this jump. While the pressure associated with this jump is significant, it does not destroy the fitting at the base of the stack. Rather, the movement of the pipe stresses the frictional forces that hold the joint to the pipe, leading to eventual coupling failure. Good design must compensate for the strong thrust that occurs at this change of direction. Successful methods include increasing the horizontal drain size and/or slope, using thrust blocks, or using restraining joints with threaded rod or similar arrangements that mechanically anchor the fitting to the entering and leaving piping. Once the water is raised and used, it is discharged to a drainage

system that includes an attendant venting system, which is responsible for the flow of air in the drainage piping network.

Air is critical to the drainage process because drainage flow is caused by sloping pipes, and the motive force is gravity. Absent air, the drainage would range from erratic to nonexistent. When the water in a pipe flows to a lower area, air must be added to replace the water, or a negative pressure zone will occur. If this zone is near a fixture, air will be drawn into the drainage system through the fixture trap with an easily identified gulping sound and very slow drain performance. This condition leads to poor performance throughout the drainage system and trap seal loss due to siphoning or blowout. The remedy for this condition is venting. At the individual fixture level, this consists of a fixture vent. As the number of fixtures increases, venting needs do as well, and a venting system evolves, with branch, circuit, and loop vents at the appropriate locations. When dealing with high-rise drainage stacks, a vent stack should be attendant, allowing for pressure equalization and relief along the height and breadth of the system. Aside from relieving pressure in the drainage system, the vent system allows air to circulate in both directions in response to the fluctuating flow in the drainage system. In many high-rise vent designs, where stacks need to offset horizontally on a given floor, a relief vent is required. Although not often highlighted, the building venting system also serves to supplement the vent for the municipal sewer, relieving noxious or even hazardous gases and allowing the sewer to drain without pressure limitation.

Fire Protection

One area that should not be overlooked in any high-rise design is the fire protection systems. As a minimum, all high-rise buildings should have sprinkler systems on each floor and standpipe systems in each stairwell. These systems have proven themselves throughout the years to significantly save both life and property. The specific type, coverage density, and outlet placement all vary based on the building type, height, and location and local fire authorities. All high-rise buildings containing fire protection systems have large, dedicated fire pumps to provide the flows and pressures required for the individual system.

While not always tasked with these system designs, plumbing engineers need to know that these systems are an integral part of the building and must account for their presence regarding equipment space, riser locations, and ceiling cavities.

Wet systems in commercial spaces must be designed as a minimum to criteria for Light Hazard (0. 10 gpm/sq. ft. over the remote 1, 500 sq. ft. of floor area).

Sprinkler piping on floors up to the 2nd floor shall be sized for street pressure only.

Standpipe systems shall be provided . In particular:

a. The standpipe risers shall be interconnected and have isolation valve for each standpipe.

b. Two four-way fire department connections shall be provided on separate streets, piped to separate standpipe risers.

c. At least one fire department connection shall be piped to the standpipe side of an isolation valve.

d. FDC's must be located at an approved location.

e. A Fire hydrant must be located within 50ft of the FDC

g. Roof and floor remote areas must be within 200 feet of hose travel distance from a protected standpipe hose connection.

Standpipe risers shall be combination standpipe/sprinkler risers using a minimum pipe size of 6 inch. One 2-1/2 inch hose connection shall be provided on every intermediate floor level landing in every required stairway and elsewhere as required.

Two separate water supplies are required for the sprinkler/standpipe system. One must be a permanent City water main connection and the second must be

a dedicated reservoir.

http://www. newcomb-boyd. com/pdf/high-rise%20article. pdf